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SUBJECT: Tracking Coverage and Lighting
for SL-2 Short Rendezvous -
Case 610

DATE: September 30, 1970

FROM: W. L. Austin

ABSTRACT

Tracking coverage for the SL-2 rendezvous maneuvers is adequate for the short rendezvous. However, the margin for the M=5 NCl maneuver computation is small enough that the effect of SL-1 and SL-2 launch vehicle dispersions on the tracking coverage for the M=5 NCl burn should be studied. One possible conclusion of such a study could be to require that the NCl burn be performed no earlier than the third apogee though such a conclusion is not substantiated by the nominal coverage data.



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(NASA-CR-113953) TRACKING COVERAGE AND
LIGHTING FOR SL-2 SHORT RENDEZVOUS
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MEMORANDUM FOR FILE

Introduction

This memorandum presents MSFN USB tracking coverage and orbital day/night cycles for the SL-2 short rendezvous opportunities (M=5, 6, and 7) occurring on the first seven days after the SL-1 launch. These data are shown in Figures 2 through 16. Table 1 contains the names of the stations used and their abbreviations.

For each M number, the minimum, average, and maximum phase angle opportunities are shown in their order of occurrence. To illustrate the rendezvous profile, the SL-2 rendezvous maneuver points, and the altitude at each apsidal crossing are shown in each figure. Also shown in each figure is the point where the slant range between SL-1/SL-2 is 300 nm. This point is labeled S/C NAV and is the point where nominal on-board navigation can begin. In each figure, time-zero is at the instant of SL-2 launch.

The rendezvous trajectories were generated by determining the minimum, average, and maximum phase angle launch opportunities (within a 700 lb SL-2 payload penalty limit) for M=5, 6, and 7 rendezvous profiles as a function of time from an SL-1 launch at 15:00 EST on July 19, 1972. These opportunities are shown in Figure 1. The circled numbers indicate the points in the launch windows used in this study. All such opportunities for an SL-2 launch were input to a computer program which utilizes a precision integration targeting scheme and impulsive burns to compute rendezvous trajectories.*

The day/night cycles and coverage times for each station were then computed using the TRACK program.** The actual minimum possible elevation angle vs. azimuth data for

*These runs were made by R. C. Purkey using the Navigation and Guidance Simulator (NAGS).

**Program TRACK is a special purpose program written by the author and C. O. Guffee. The program interrogates a tape written by NAGS.

each station (as reported in Reference 1) were used to compute the station coverages. Thus, the appearance of keyholes. Where the keyhole affects the coverage, the station name is enclosed in parenthesis to call attention to the holes in the coverage.

Coverage Analysis

Nominally, on-board VHF ranging and sextant navigation can commence once the range between the vehicles is less than 300 nm. Thereafter, the on-board capability for maneuver computation can be used and MSFN support is not so critical. Reviewing Figures 2 through 16 shows that nominally, there is adequate opportunity for on-board navigation prior to the NCC (and subsequent) maneuvers in all cases. This assumes that 32 minutes is sufficient to perform the navigation measurements and prepare for the maneuver. Because the ground is the prime source for computing solutions for the NC1 and NC2 maneuvers, the available MSFN coverage for the insertion to NC1 and NC1 to NC2 periods is critical.

In general, coverage (especially between insertion and NC1 and between NC1 and NC2) by two S-band stations (at least three minutes each) which are sixty or more degrees apart in longitude is sufficient to compute good solutions for NC1 and NC2. A third station pass is required for up-linking. The last data used in the computation must be taken no later than ten minutes prior to the uplink station pass as the ground requires ten minutes to compute and check the solution. The uplink station pass must occur no later than ten minutes prior to the maneuver as the data must be in the command module computer at least ten minutes prior to the maneuver.* This station pass geometry will be used as a strict criteria to judge the adequacy of MSFN coverage, however, a recent MSC study** has shown that single station tracking produces an adequate, though degraded, state vector. The availability of a single tracking station and a suitable uplink station can be considered a "relaxed" criteria though where on-board navigation is not possible, the availability of a backup MSFN station is highly desirable.

*These general criteria on adequate tracking requirements to obtain NC1 and NC2 solutions were given to the writer in a telephone conversation with J. Shreffler/MSC-MPAD on July 24, 1970.

**Personal conversation between D. A. Corey and P. Pixley MSC/MPAD.

Application of these criteria to the coverage shown for the insertion to NC1 and NC1 to NC2 periods in Figures 2 through 16 show that they are met or exceeded for all of the NC1 to NC2 periods. They are also met for the insertion to NC1 periods for all M=6 and 7 opportunities. However, the strict criteria are not met for the insertion to NC1 periods for the M=5 opportunities. In particular, the criteria are not met for the Day 1, M=5, minimum phase angle opportunity (Figure 2) which is the nominal for SL-2 launch. The relaxed criteria are met in that Texas or Guymas could be used for tracking and the NC1 maneuver pad could be uplinked via Madrid. The Madrid pass is only 3.5 minutes long, however, and the effect of trajectory dispersions on its suitability as an uplink pass should be studied. The Madrid pass is longer for the M=5 average and maximum phasing opportunities and for the day 6, M=5 opportunity and is less likely to be a problem. The Guymas pass develops a hole in the coverage for the M=5, maximum phasing opportunity but there is still more than 3.5 minutes of continuous coverage and it should be good enough to serve as a backup station.

On succeeding days with short rendezvous opportunities, (Days 2, 6, and 7), any of the M=6 or 7 opportunities will provide adequate coverage for ground computed NC1 and NC2 maneuvers.

After NC2, the spacecraft navigation and maneuver computations are prime and the ground serves as a backup. The availability of a second or backup tracking station is of less importance for the remaining maneuvers.

The other constraints on maneuver computation time and uplinking remain the same. The data used to compute NCC will also be used to compute NSR and both burns will be uplinked as a pair.

Reviewing the figures shows that these criteria are met for all opportunities excluding the Day 2, M=7 maximum and the Day 7, M=7 average and maximum phase angle opportunities. Where these criteria are not met, one possible solution is to uplink NCC and NSR (assuming a good NC2 execution) along with the NC2 maneuver. MSC is currently evaluating the quality of the maneuver computation for this procedure and the results should be available the latter part of October. Note that in all cases, the spacecraft is within 300 miles of the target sufficiently in advance of the NCC maneuver to allow adequate opportunity for on-board tracking.

Summary and Conclusions

Tracking coverage for the M=5, 6, and 7 minimum, average, and maximum phase angle launch opportunities (within a 700 lb SL-2 payload penalty limit) for the first seven days after SL-1 launch was presented and analyzed from the viewpoint of coverage between burns.

In all of the M=6 and M=7 cases, there are at least two tracking station passes separated by at least 60 degrees, and an uplink station pass available to support the NC1 and NC2 rendezvous maneuvers. Similar coverage is available to support the NC2 maneuver for the M=5 cases but only one tracking station is available to support the NC1 maneuver. Another tracking station is available for backup in these cases. There is, however, no backup for the uplink station, (Madrid) for the M=5 cases and in the case of the M=5 minimum phasing case, the Madrid pass is only 3.5 minutes long because of the station keyhole. Consequently, additional study should be performed to insure that expected launch vehicle dispersions do not seriously degrade the possibility of uplinking the NC1 maneuver parameters through Madrid. Note that this case is the nominal SL-2 launch.

Since the data for this study was generated, the planned rendezvous profile has changed somewhat. The new profile places the NC1 maneuver at the second apogee after insertion for the M=6 and M=7 cases as well as for the M=5 case. This has the effect of reducing the pre-NC1 tracking coverage for the M=6 and M=7 cases to that for the M=5 case, i.e., single station tracking with a single station available for uplink. This amplifies the need to study the tracking coverage as it is affected by launch vehicle dispersions. A possible conclusion of such a study might be that from the tracking coverage point of view, the first rendezvous maneuver should be slipped to the third apogee and the M=5 rendezvous dropped altogether. While this would have no effect on the number of days on which SL-2 launch could occur, it would increase the nominal time to rendezvous. However, the data of this study does not substantiate such a conclusion.

The tracking coverage shown for the backup ground computed NCC and NSR maneuvers meets MSC's general criteria excluding the Day 2, M=7, maximum and Day 7, M=7 average and maximum phase angle opportunities. MSC is currently studying the validity of uplinking the NC2, NCC and NSR maneuvers all based on pre-NC2 tracking. Adequate opportunity for on-board tracking is available for these maneuvers.

W. L. Austin

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1025-WLA-r1

Attachments

Figures 1-16

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Reference

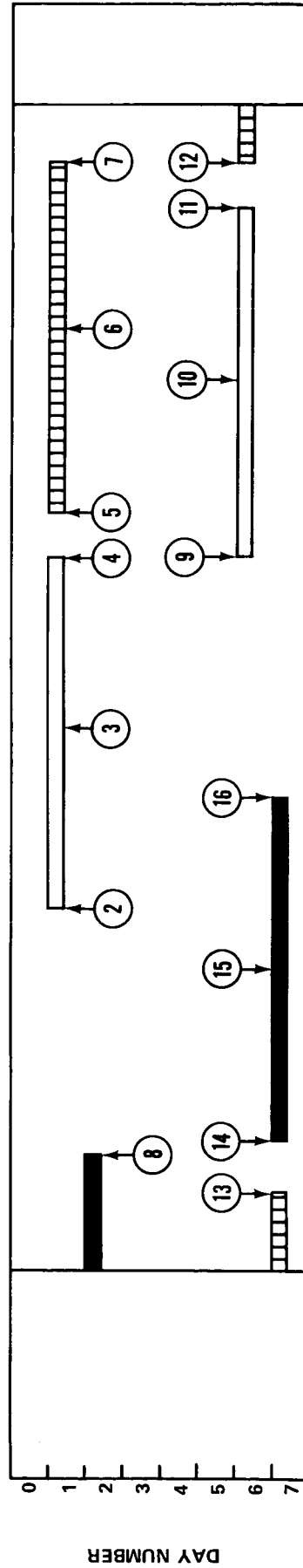
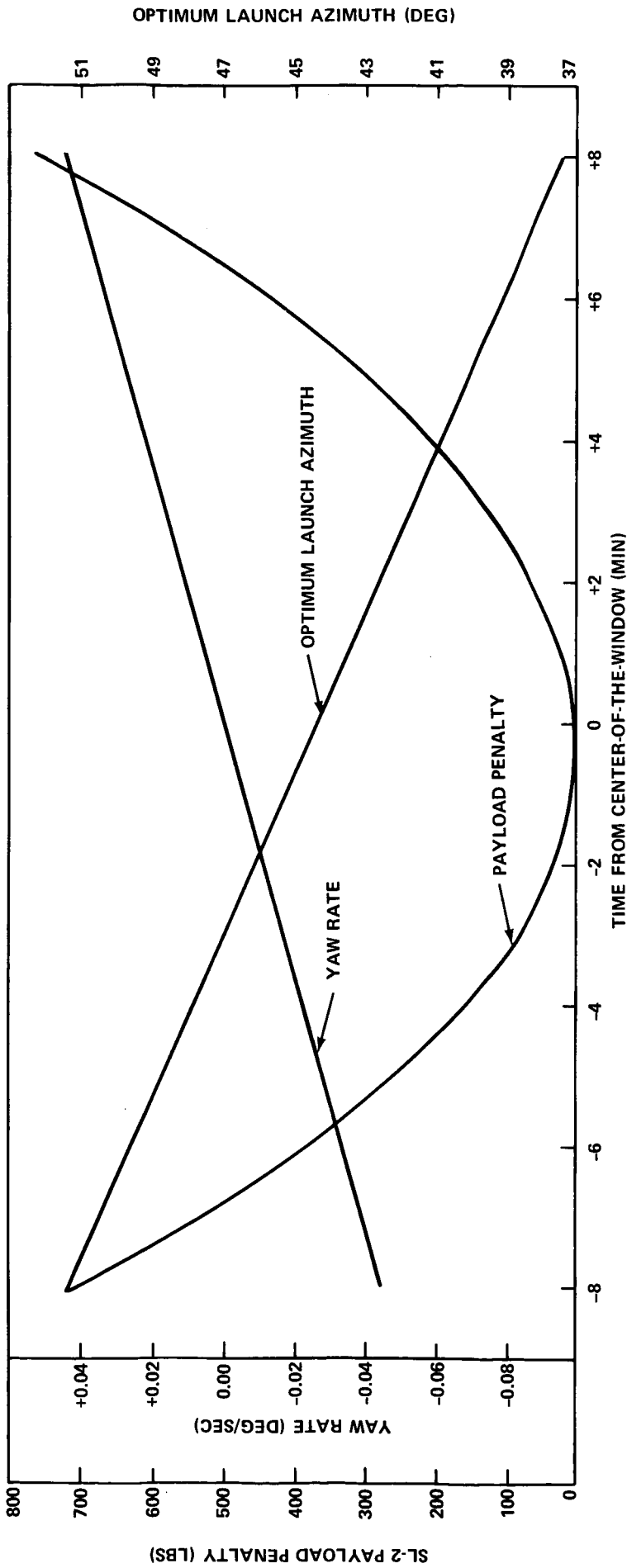
1. Manned Space Flight Network Antenna Coverage Data,
Goddard Space Flight Center, November, 1967.

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TABLE 1

STATION NAMES AND ABBREVIATIONS

<u>Station Name</u>	<u>Location</u>		<u>Abbreviation</u>
	<u>Latitude</u>	<u>Longitude</u>	
Antigua	17.016N	61.753W	ANG
Ascension Island	7.955S	14.328N	ACN
Bermuda	32.351N	64.658W	BDA
Canary Island	27.765N	15.635W	CYI
Canberra	34.415S	148.977E	CNB
Carnarvon	24.908S	113.724E	CRO
Corpus Christi, Texas	27.654N	97.378W	CCT
Goldstone	35.342N	116.873W	GDS
Grand Bahama Island	26.632N	78.238W	CBM
Guam	13.309N	144.734E	GWM
Guyamas	27.963N	110.721W	GYM
Hawaii	22.125N	159.665W	HAW
Madrid	40.455N	4.167W	MAD
Merritt Island	28.508N	80.710W	MIL



NOTE: CIRCLED NOS. CORRESPOND TO FIGURE NO.

FIGURE 1 - SL-2 SHORT RENDEZVOUS OPPORTUNITIES FOR THE FIRST SEVEN DAYS AFTER AN SL-1 LAUNCH AT 3:00 PM EST JULY 19, 1972

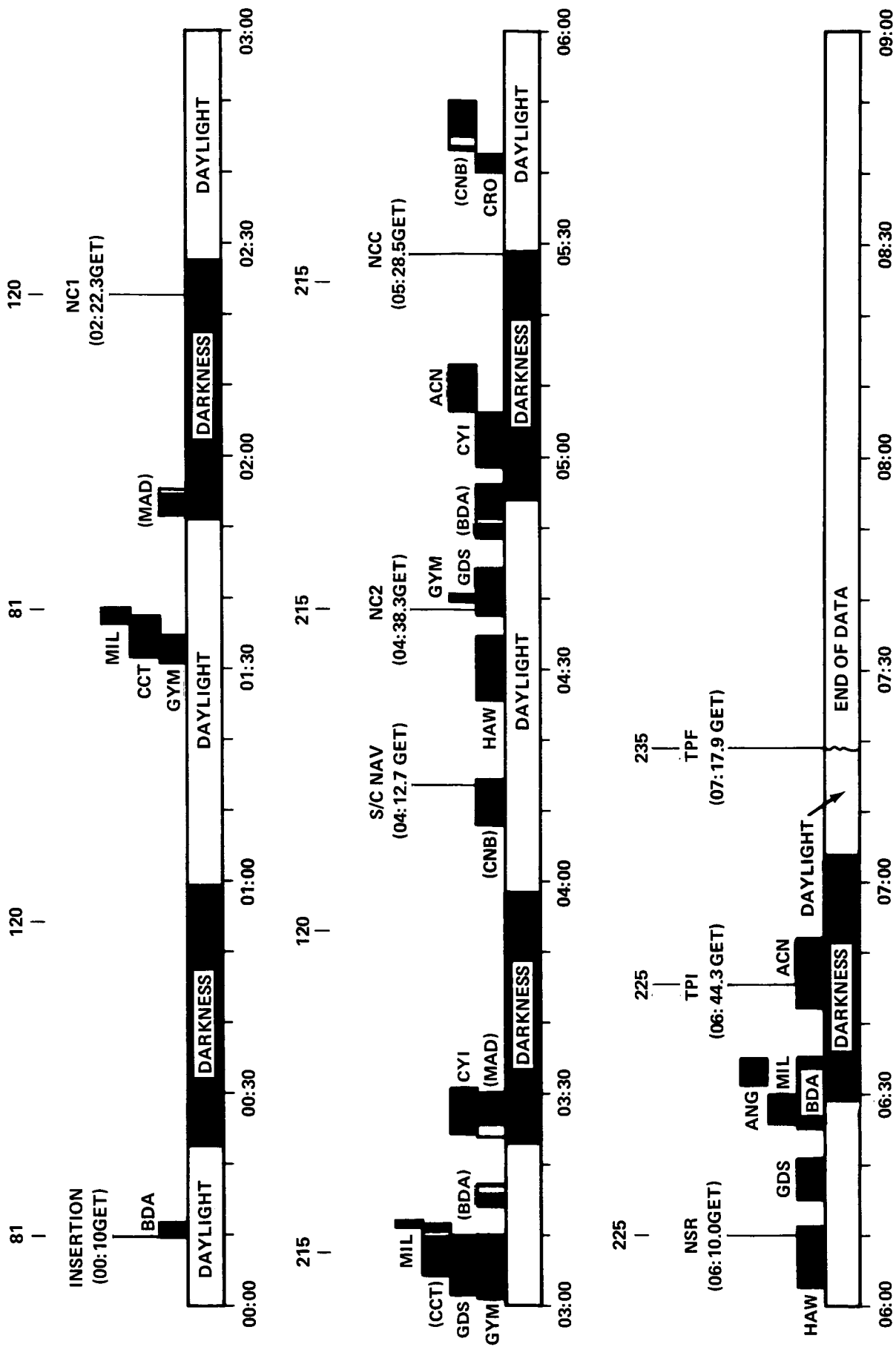


FIGURE 2 - M - 5 SL-2 MINIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 1 SL-2 LAUNCH AND AN SL-1 3:00 PM JULY 19, 1972 LAUNCH

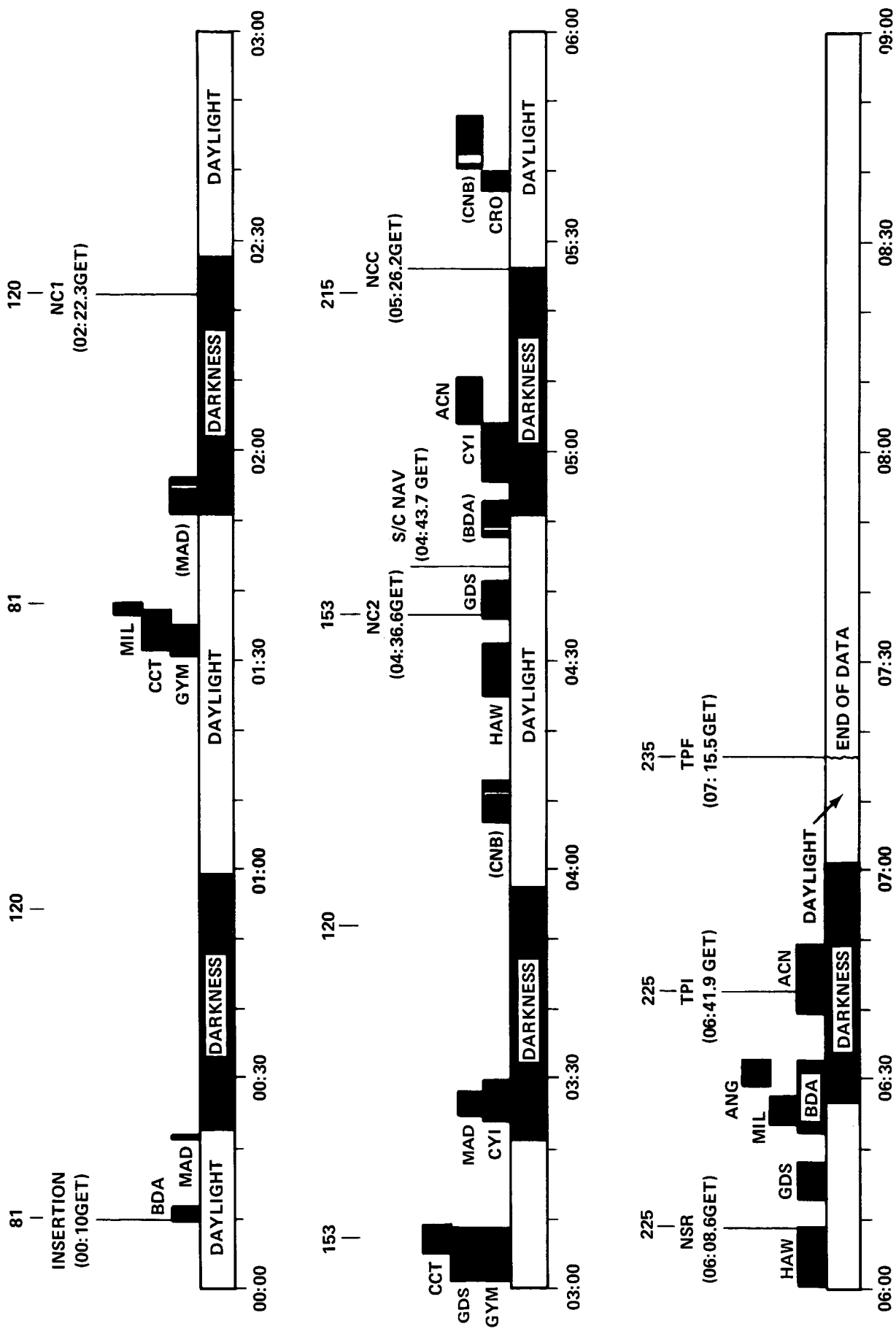


FIGURE 3 - M = 5 SL-2 AVERAGE PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 1 SL-2 LAUNCH AND AN SL-1 LAUNCH AT 3:00 PM JULY 19, 1972

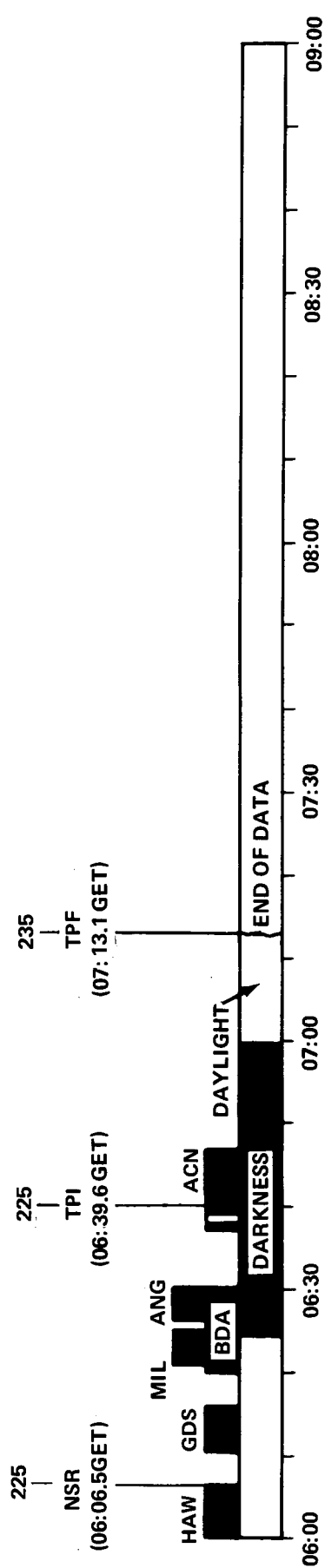
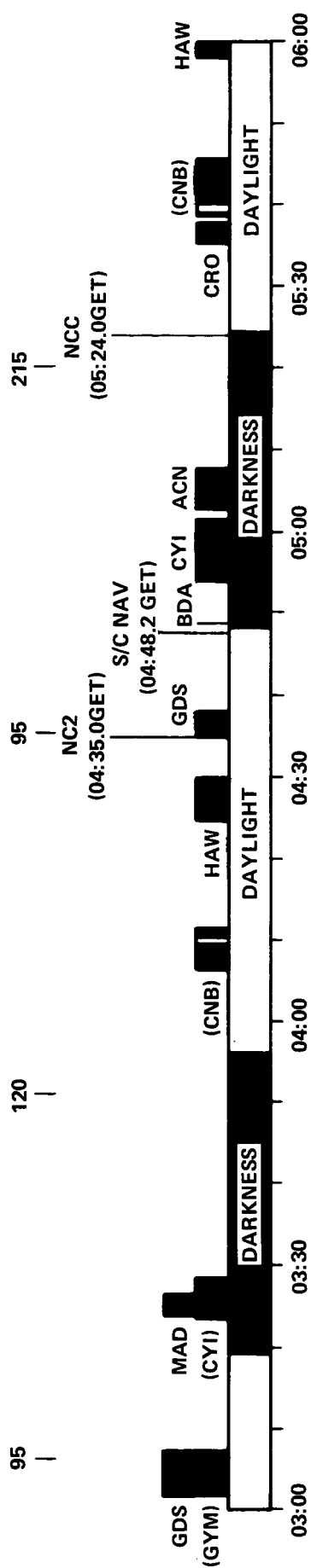
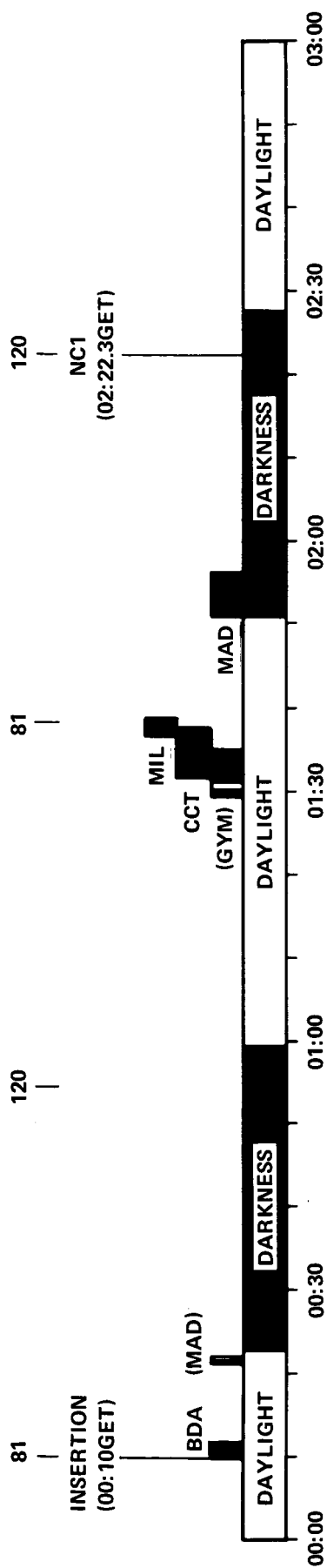


FIGURE 4 - M = 5 SL-2 MAXIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 1 SL-2 LAUNCH AND AN SL-1 LAUNCH AT 3:00 PM JULY 19, 1972

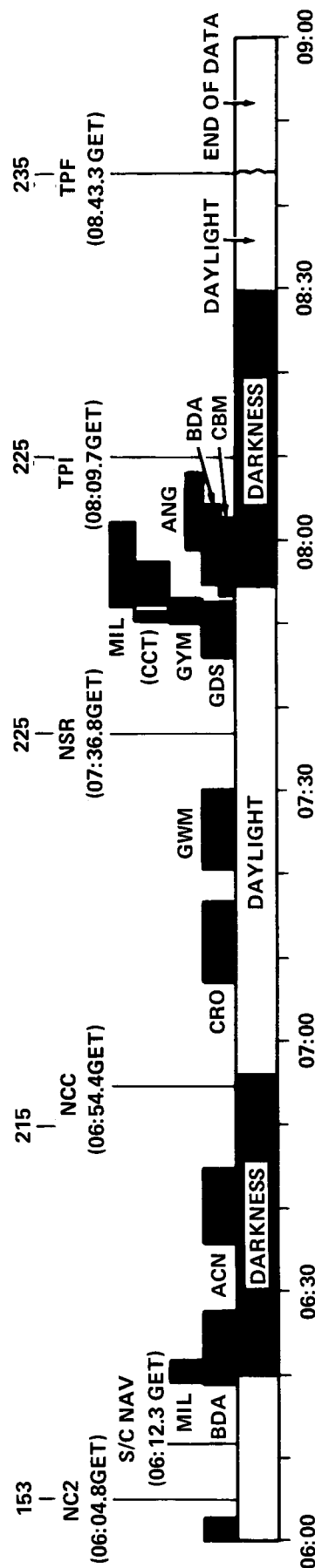
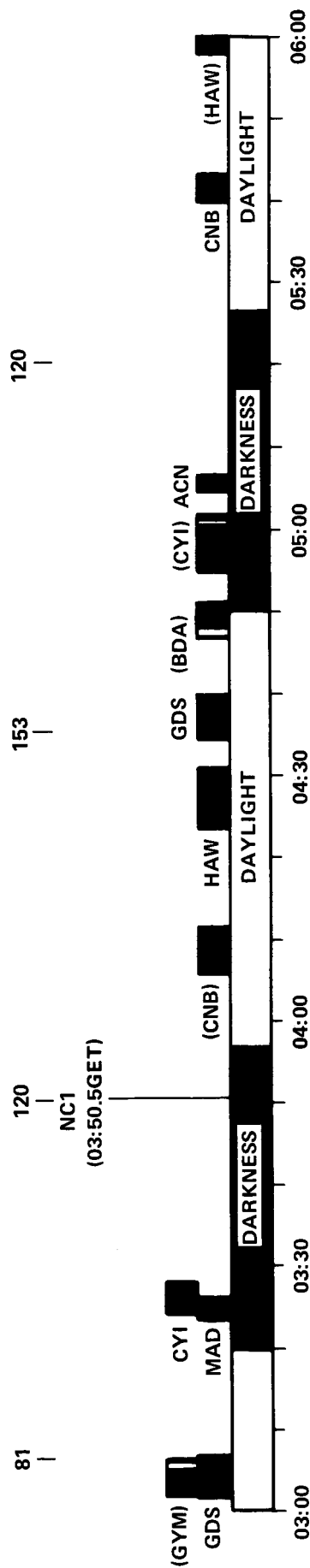
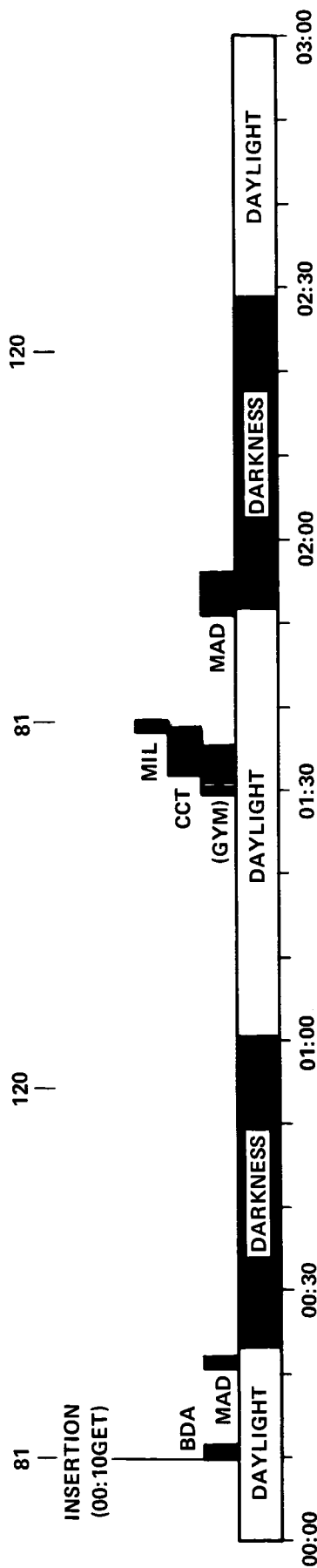


FIGURE 6 - M = 6 SL - 2 AVERAGE PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR AN SL-1 3:00 PM
JULY 19, 1972 LAUNCH AND AN SL-2 DAY 1 LAUNCH

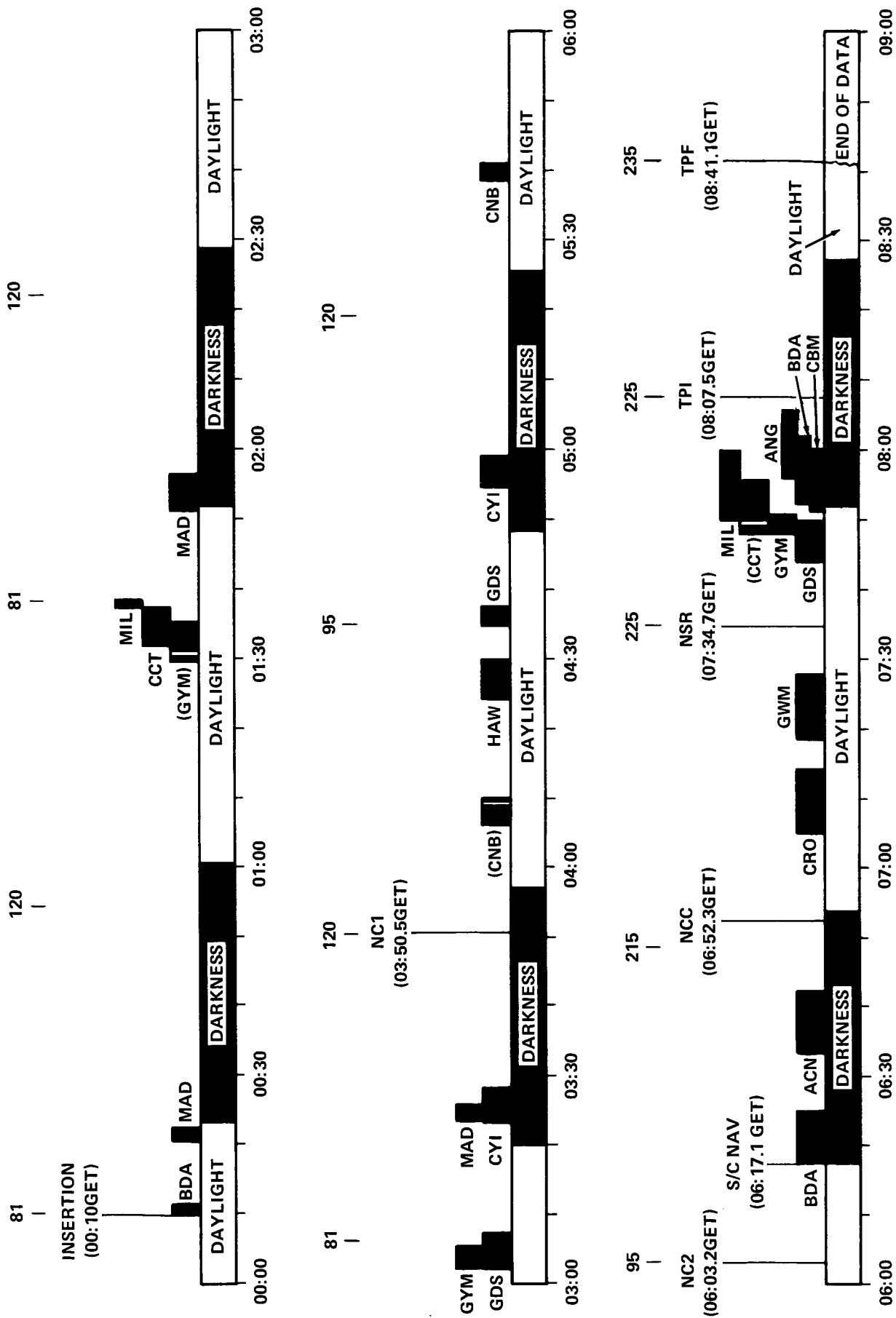


FIGURE 7 - M = 6 SL - 2 MAXIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR AN SL-1 3:00 PM
JULY 19, 1972 LAUNCH AND AN SL-2 DAY 1 LAUNCH

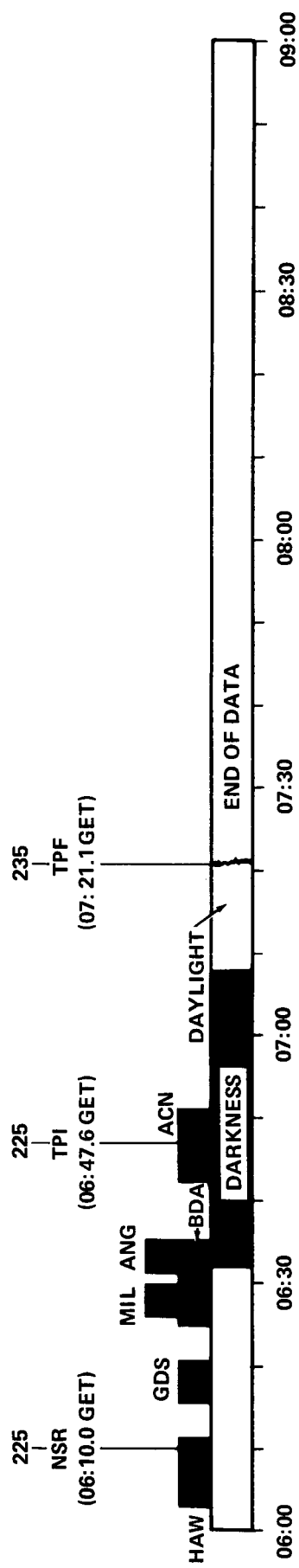
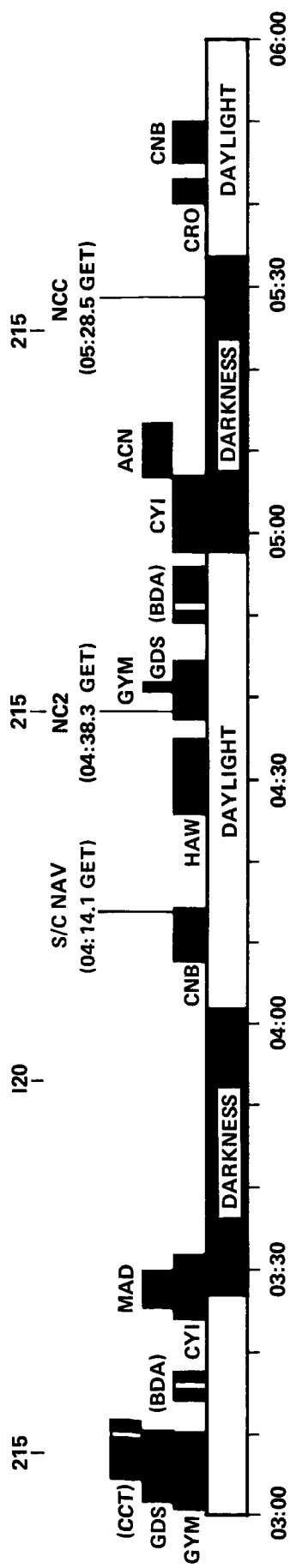
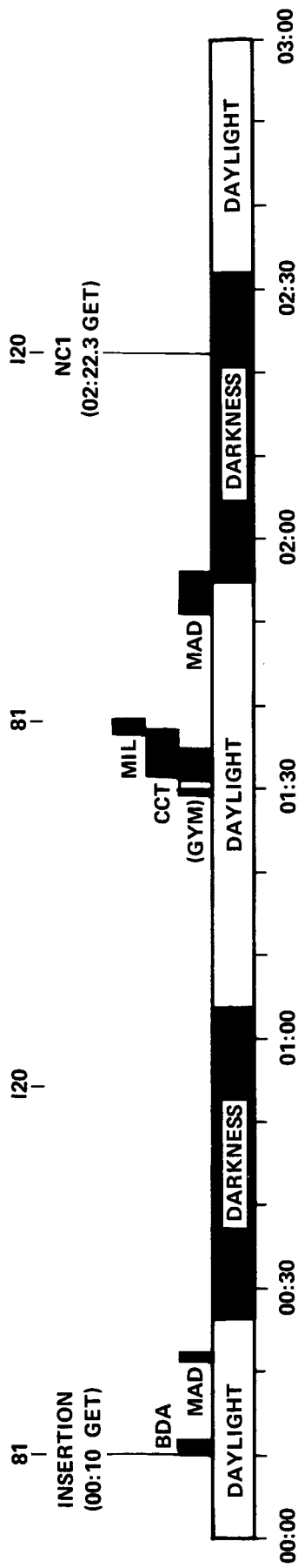


FIGURE 9 - M = 5 SL-2 MINIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A
DAY 6 SL-2 LAUNCH AND AN SL-1 3:00 PM JULY 19, 1972 LAUNCH

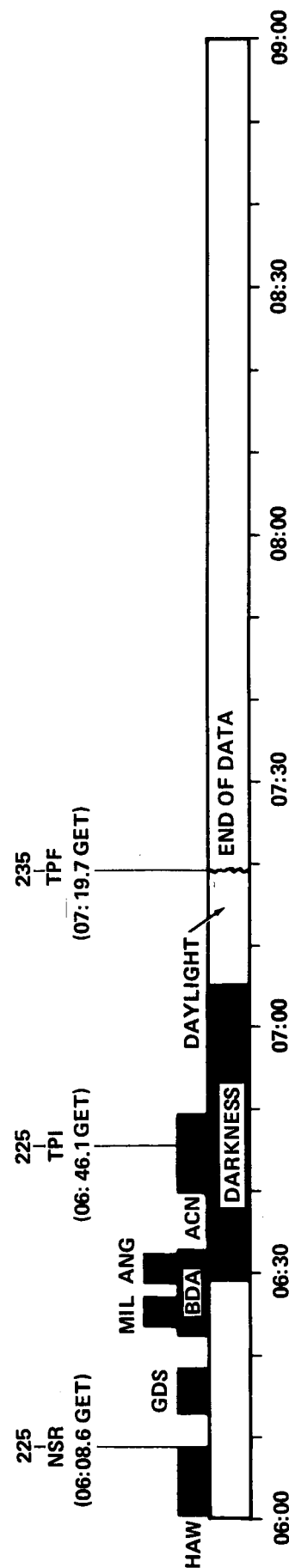
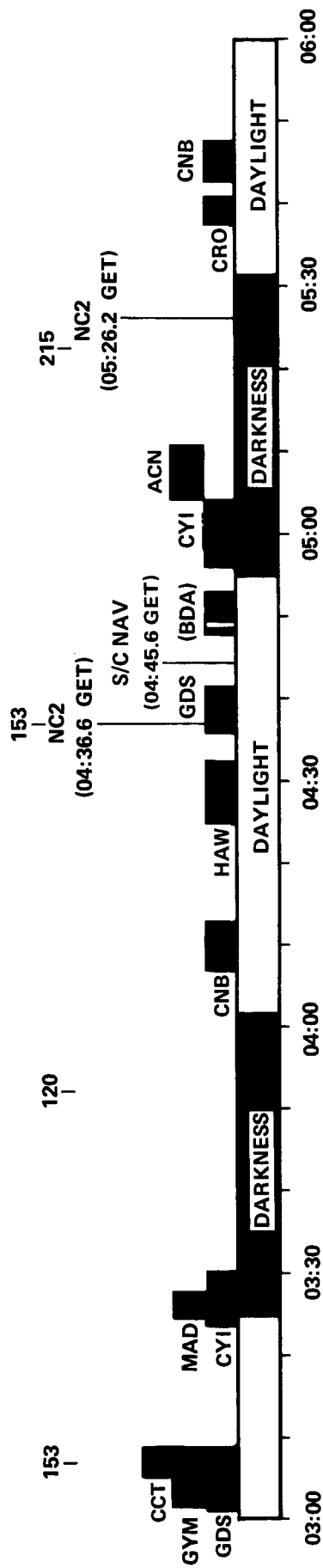
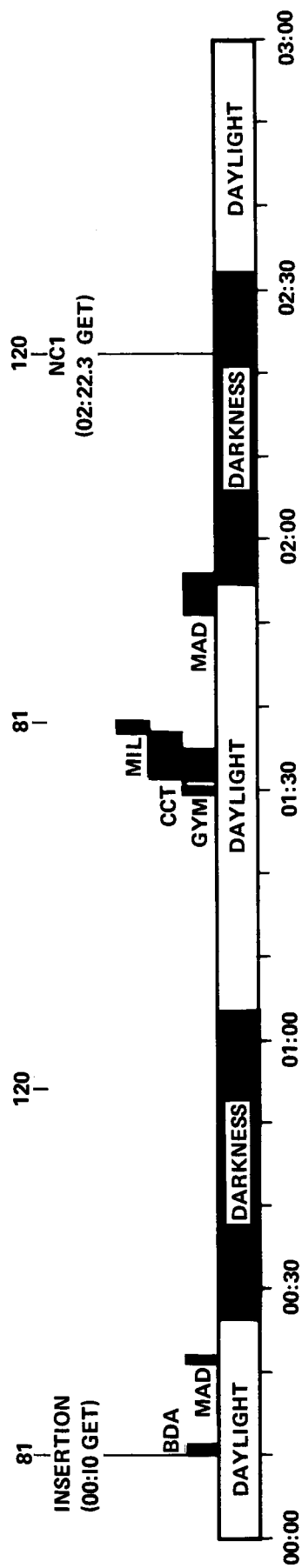


FIGURE 10 - M = 5 SL-2 AVERAGE PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 6 SL-2 LAUNCH AND AN SL-1 LAUNCH AT 3:00 PM JULY 19, 1972

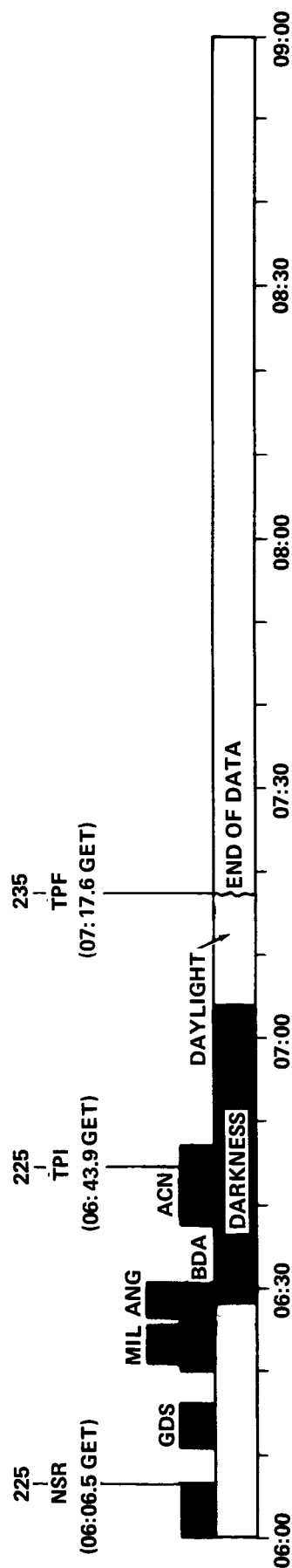
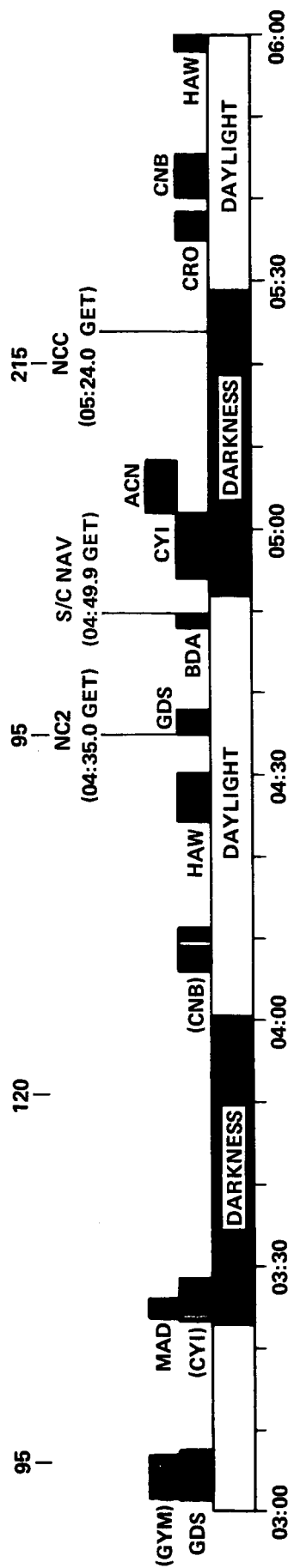
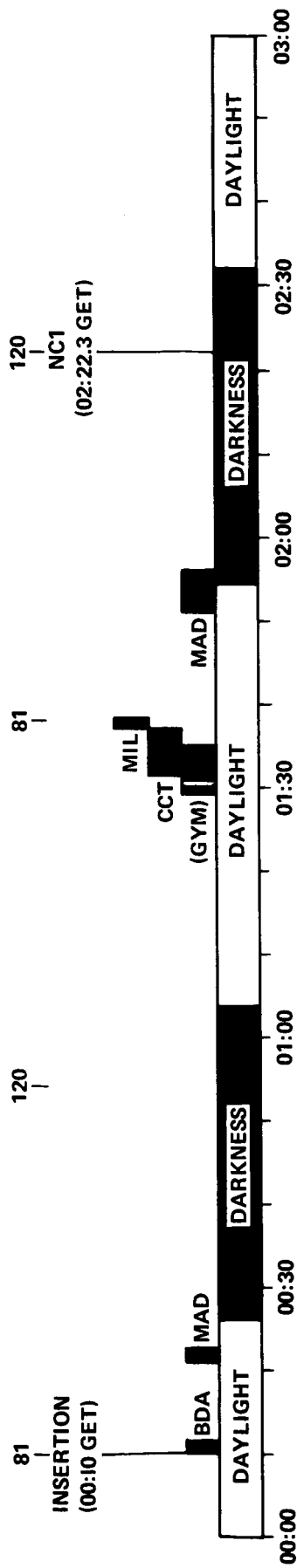


FIGURE 11 - M = 5 SL-2 MAXIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 6
SL-2 LAUNCH AND AN SL-1 LAUNCH AT 3:00 PM JULY 19, 1972

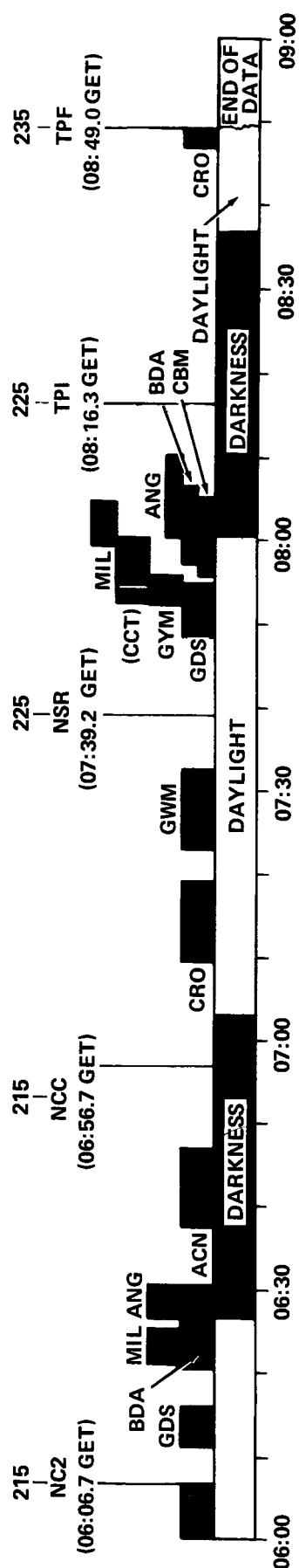
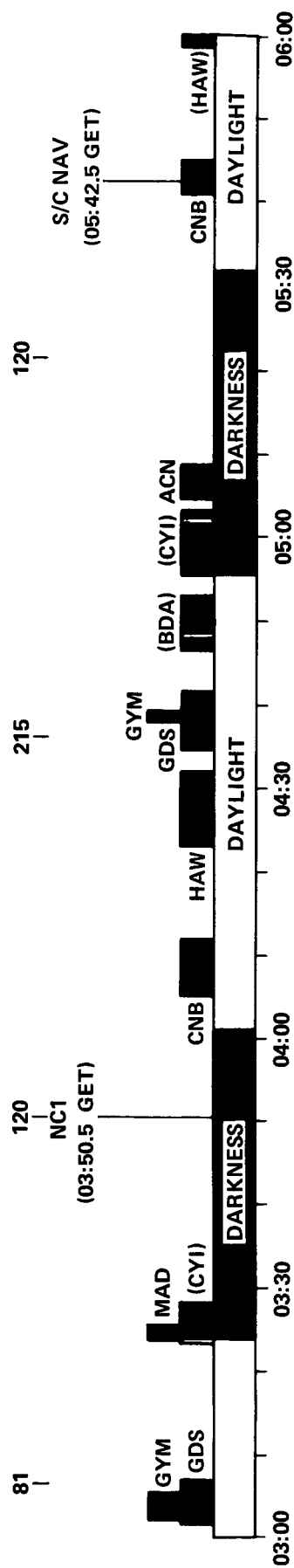
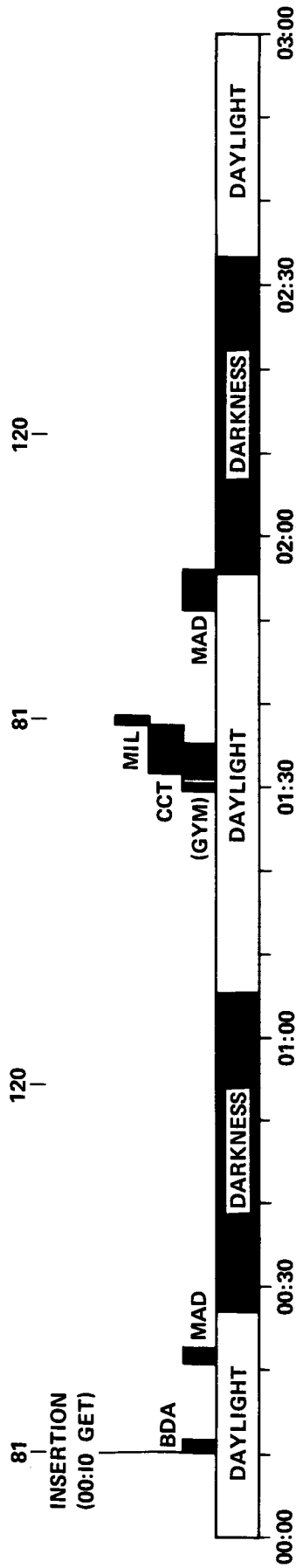


FIGURE 12 - SL-2 M = 6 MINIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR AN SL-1 3:00 PM JULY 19, 1972 LAUNCH AND AN SL-2 DAY 6 LAUNCH

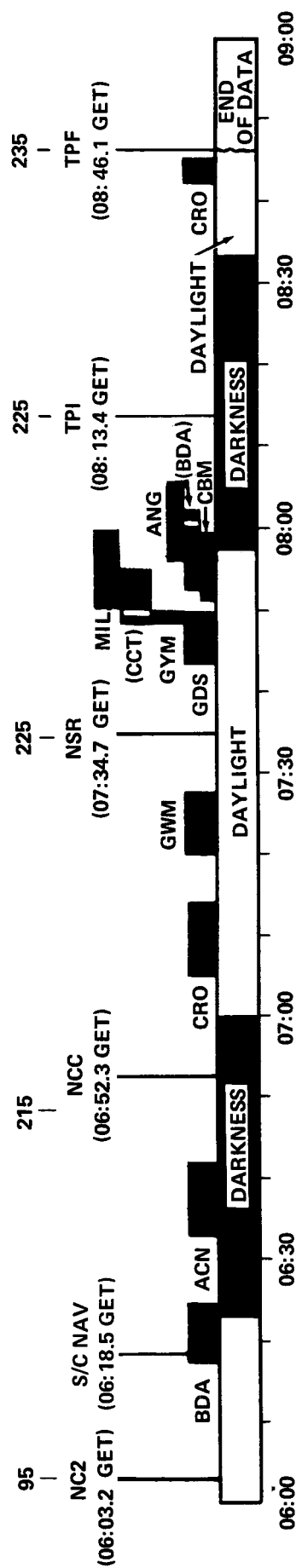
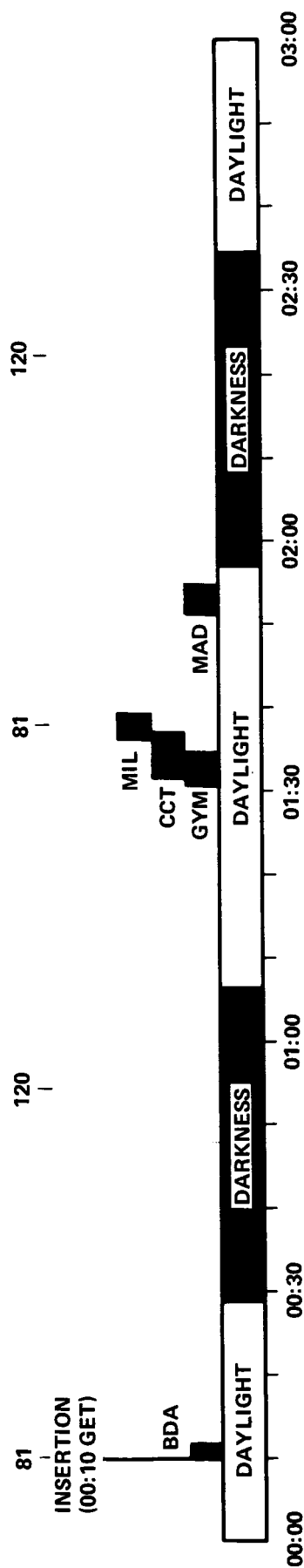


FIGURE 13 - SL-2 M = 6 MAXIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR AN SL-1 3:00 PM JULY 19, 1972 LAUNCH AND AN SL-2 DAY 7 LAUNCH

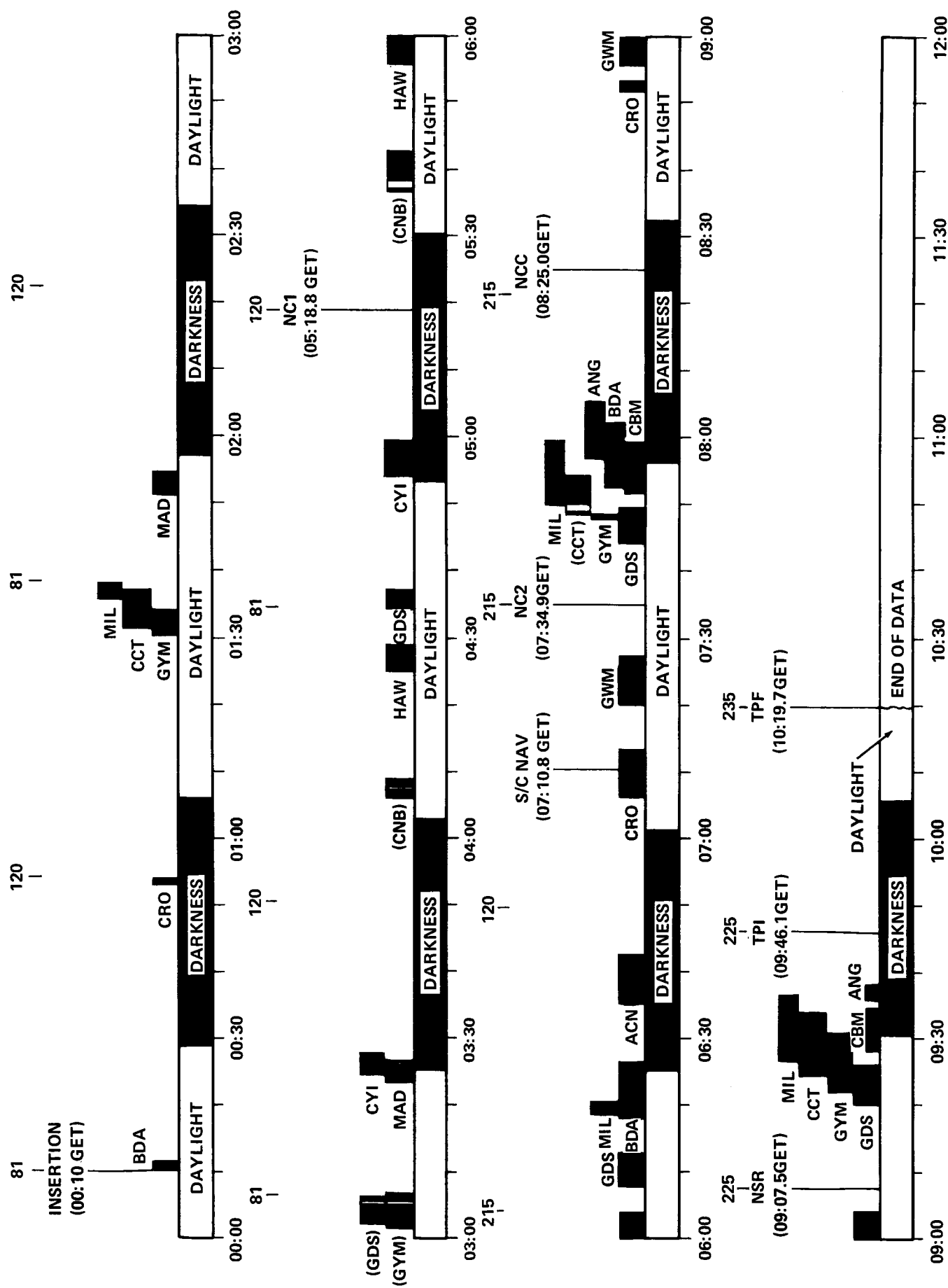


FIGURE 14 - M = 7 SL - 2 MINIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 7 SL-2 LAUNCH AND AN SL-1 3:00 PM JULY 19, 1972 LAUNCH

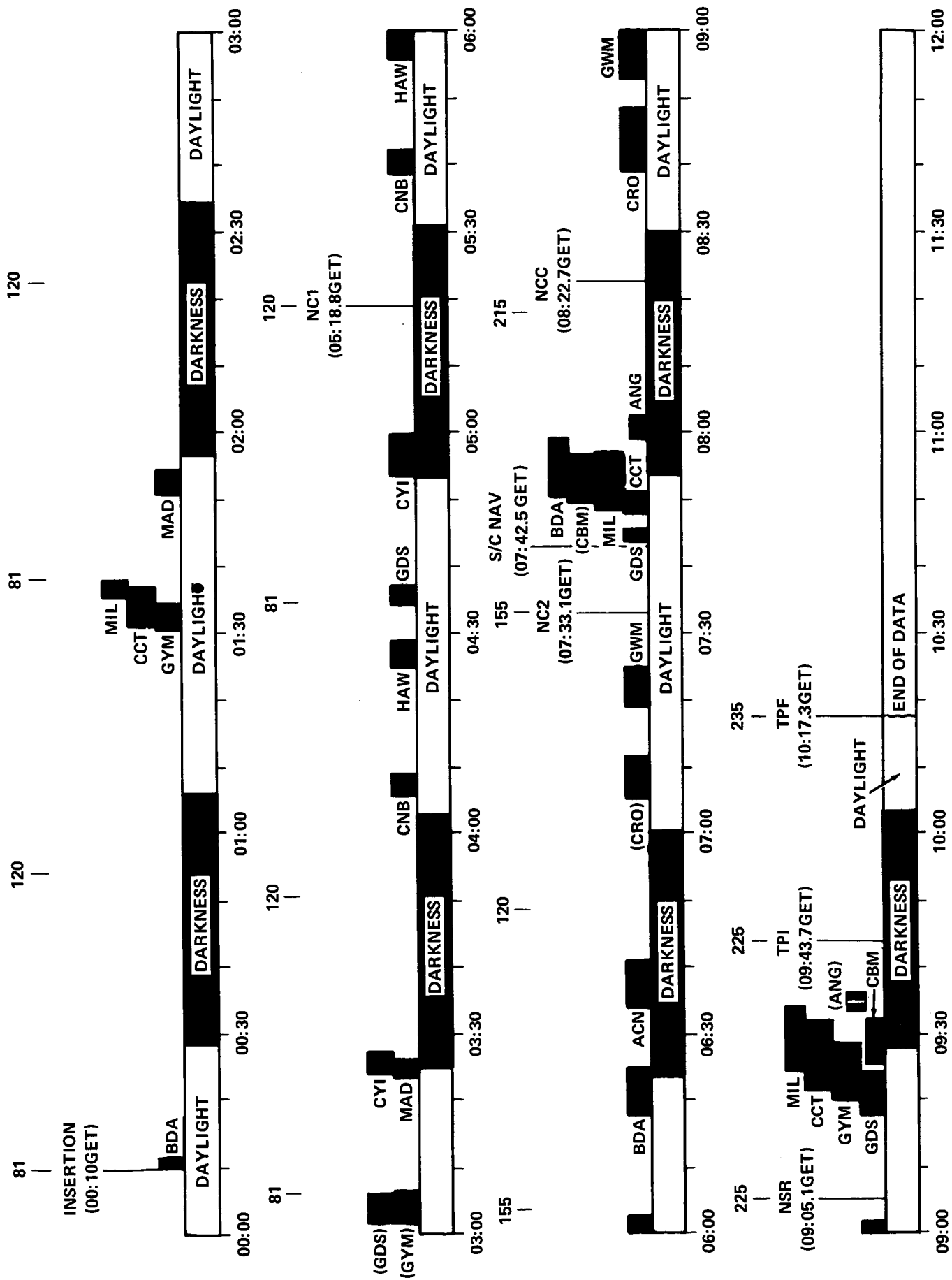


FIGURE 15 - M - 7 SL-2 AVERAGE PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 7 SL-2 LAUNCH AND AN SL-1 3:00 PM JULY 19, 1972 LAUNCH

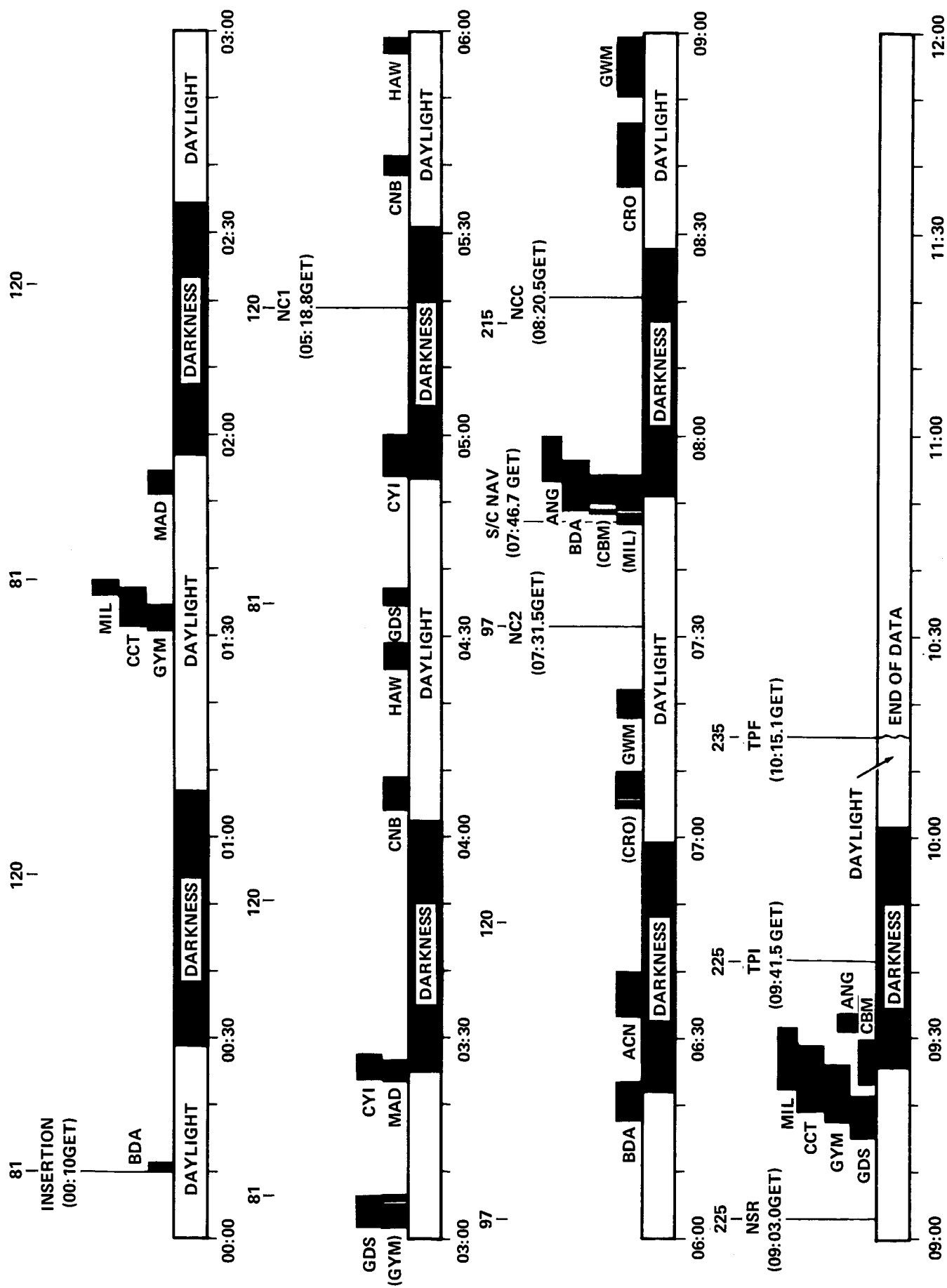


FIGURE 16 - M - 7 SL-2 MAXIMUM PHASE ANGLE TRACKING COVERAGE AND LIGHTING FOR A DAY 7 SL-2 LAUNCH AND A 3:00 PM JULY 19, 1972 LAUNCH